Agro-Environmental Impact Assessment and Farm Management

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MAICH - Agriculture & Environment

Agro-Environmental Impact Assessment and Farm Management

- Course objectives
  - Understand the role of agriculture in shaping human societies and its effect on earth's ecosystems
  - Explore modern agriculture's role in meeting the needs of a fast growing world population and its impact on the environment, economy and the society
  - Learn concept and methods to assess the sustainability of farm management systems

Course Outline

- Introduction
  - *Historical perspective - Development of Agriculture*
  - *Green Revolution - Food Security*
- Environmental Impact
  - *Natural resources - Ecotoxicity*
  - *Climate Change - Energy*
  - *Biodiversity - Genetic Engineering*
- Sustainable Agriculture
  - *Principles of Ecological Agriculture*
- Soils - Nutrient budgets
- Farm Management Systems
  - *Low-input Sustainable Agriculture*
  - *Integrated Farming Systems*
- Environmental Impact Assessment - LCA
- Conventional vs. Organic Agriculture
  - *Energy - Carbon sequestration*
  - *Sustainability*
  - *EU Policies*

History of Agriculture

- Hunter - Gatherers
- Neolithic Revolution
  - *Domestication of Plants and Animals*
  - *Diffusion of Agriculture*
- Agricultural Industrialization
- The “Green Revolution”
- Modern Agribusiness

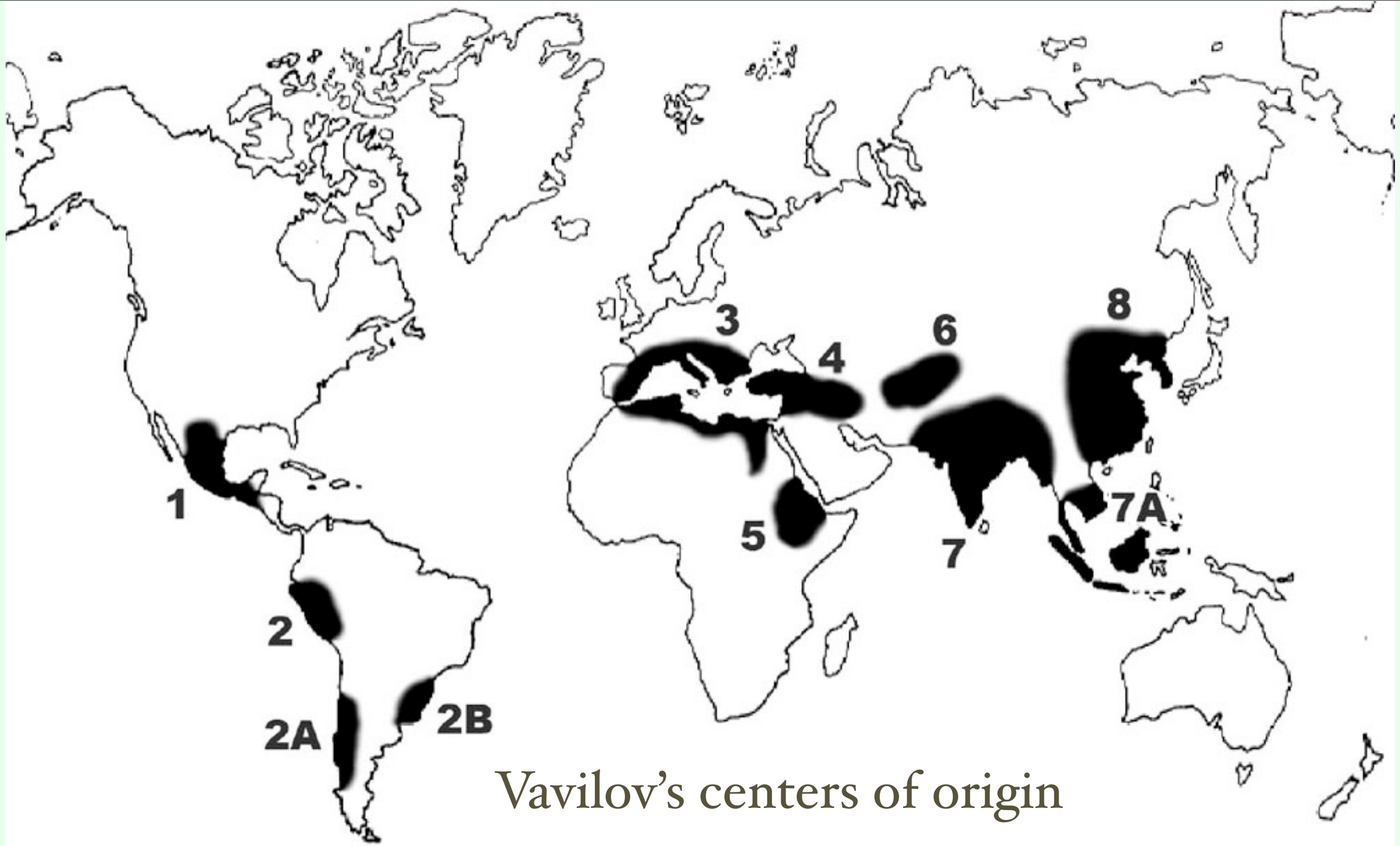
Neolithic Revolution

Domestication of Plants and Animals

- Seed Agriculture - Fertile Crescent, western India, northern China, Ethiopia, southern Mexico (11,000 b.p.)

- Vegetative Planting - Southeast Asia, West Africa, Northwest S. America (3,000-5,000 b.p.)

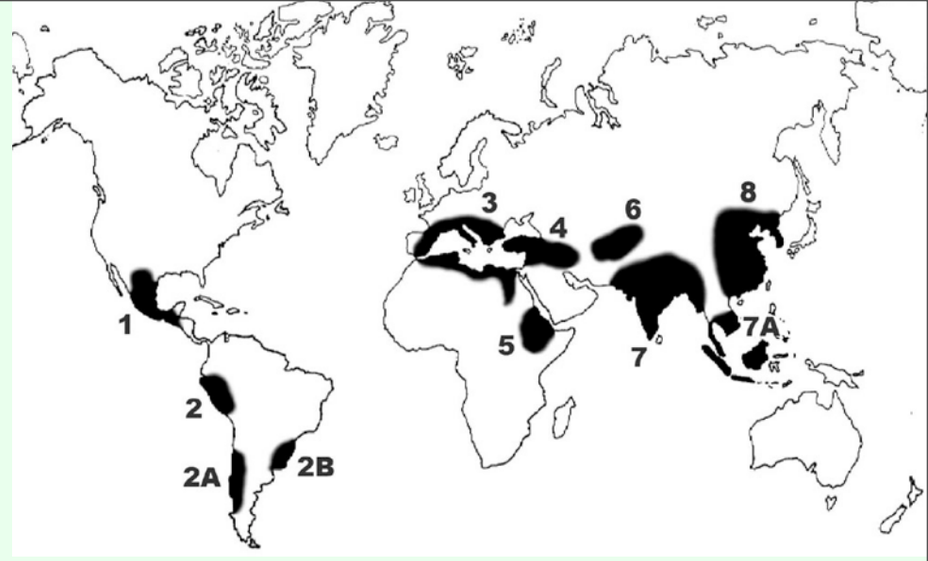
- Rice, wheat, and corn account for more than 50% of population's food calories and were among the first plants domesticated (along with millet, sorghum wheat, rye, barley).



Vavilov's centers of origin

1) Mexico-Guatemala, (2) Peru-Ecuador-Bolivia, (2A) Southern Chile, (2B) Southern Brazil, (3) Mediterranean, (4) Middle East, (5) Ethiopia, (6) Central Asia, (7) Indo-Burma, (7A) Siam-Malaya-Java, (8) China.

Vavilov's Centers of Origin



- 1 - China - lettuce, rhubarb, soybean, and turnip;
- 2 - India - cucumber, rice, mango, and Asian cotton;
- 2a - Indochina - banana, coconut, and rice;
- 3 - Central Asia - almond, flax, and lentil;
- 4 - Near East - alfalfa, apple, cabbage, and rye;
- 5 - Mediterranean - celery, chickpeas, and durum wheat;
- 6 - Ethiopia - coffee, grain sorghum, and pearl millet;
- 7 - Mexico & Guatemala - maize, lima bean, papaya, and upland cotton;
- 8 - Bolivia, Ecuador & Peru - potato, tomato, and Egyptian cotton;
- 8a - Southern Chile - potato.

Neolithic Revolution

- Domestication of Animals
  - *Dog was probably first.*
- Early domesticated animals:
  - *cattle, oxen, pigs, sheep, goats, guinea pigs, llama*
- Vital role of domesticated animals in increase in agricultural production and success (and environmental impact)
- Relationship of agriculture and domesticated animals to success of particular cultures/languages: Indo-European Horsemen

Modern Agricultural Revolution

Technology allows much greater production (surplus) with less human labor.

- Metal plows, Reapers, Cotton Gin
- Tractors (Internal Combustion Engine)
- Combines
- Chemical Pesticides/ Fertilizers
- Hybrid and genetically modified crops

Modern Agricultural Revolution

Agribusiness - The industrialization of agriculture in the core countries.

- Fewer crops
- higher output
- larger farms
- very little human labor (<2% in US)

Classifying Agricultural Regions

- Shifting Cultivation
- Pastoral Nomadism
- Intensive Subsistence Agriculture
- Mixed Crop and Livestock Farming
- Dairy Farming
- Grain Farming
- Livestock Ranching

Shifting Cultivation

Vegetation "slashed" and then burned. Soil remains fertile for 2-3 years. Then people move on.

- where: Less developed world. Amazon, Central and West Africa, Southeast Asia (Indochina, Indonesia, New Guinea)
- crops: upland rice (S.E. Asia), maize and cassava (manioc) (S. America), millet and sorghum (Africa)

Declining at hands of

ranching and logging.

Mixed Crop and Livestock Farming

- Where: Ohio to Dakotas, centered on Iowa; much of Europe from France to Russia
- crops: corn (most common), soybeans
- most product fed to pigs and cattle
- Concentrated Animal Feeding Operations (CAFOs) - inefficient use of natural resources
  - *Pounds of grain to make 1 lb. beef: 10*
  - *Gallons of water to make 1 1b wheat: 25*
  - *Gallons of water to make 1 1b. beef: 2500*

Grain Farming

- Where: worldwide, but U.S., Russia predominant
- Crops: wheat
  - winter wheat
  - spring wheat
- Highly mechanized: *combines, worth hundreds of thousands of dollars used for harvest.*

Livestock Ranching

Where: arid or semi-arid areas of western U.S., Argentina, Brazil, Uruguay, Spain and Portugal.

History: initially open range, now sedentary with transportation changes.

Livestock Ranching

Environmental effects:

1) overgrazing has damaged much of the world's arid grasslands
(< 1% of U.S. remain!)

2) destruction of the rainforest is motivated by desire for cattle ranches

Mediterranean Agriculture

- Where: areas surrounding the Mediterranean, California, Oregon, Chile, South Africa, Australia
- Climate has dry season during the summer. Landscape is mountainous.
- crops: olives, grapes, nuts, fruits and vegetables; winter wheat
- High quality land is being lost to suburbanization; initially offset by irrigation

Plantation Farming

- large scale mono-cropping of profitable products not able to be grown in Europe or U.S.
- where: tropical lowland
- crops: cotton, sugar cane, coffee, rubber, cocoa, bananas, tea, coconuts, palm oil.

The Green Revolution in Agriculture

The term *green revolution* refers to the development and adoption of high yielding cereal grains in the less developed world during the 1960s, 1970s, and 1980s.

The Green Revolution

- The US agricultural industry has been engaged in selective breeding for high-yielding crops over the past century
- Over the last 50 years or so, more intensive use of fertilizers, pesticides, mechanical farm equipment, and irrigation has boosted the productivity of these high-yield crops even more
- There has been a threefold increase in agricultural productivity over the past 50 years

History of Green Revolution

- 1943 - Rockefeller Foundation begins work on short stature hybrid corn in Mexico
- 1960s - Hybrid strains of rice, wheat, and corn show great success in S.E. Asia, and Latin America.
- 1970 - Head of Mexican program, Borlaug, wins Nobel Peace Prize
- 1990s - Growth in food supply continues, but slows to below the rate of population growth, as the results of unsustainable farming practices take effect.

The Green Revolution

- Wheat was the major crop behind the green revolution
- Efforts were made to breed wheat varieties that would grow well in tropical to subtropical areas
- A dwarf variety of wheat was developed that was resistant to *lodging*, or falling over due to the weight of the grain (a problem when wheat is heavily fertilized and produces a lot of large grains).

The Green Revolution

- These high-yielding dwarf varieties of wheat (and later rice) increased food production dramatically in places like Mexico, India, Pakistan, and the Philippines

Norman Borlaug – Nobel Peace Prize, 1970

Green Revolution

Gains were made by:

- Dwarf varieties: plants are bred to allocate more of their photosynthetic output to grain and less to vegetative parts.
- Planting in closer rows, allowed by herbicides, increases yields.
- Bred to be less sensitive to daylength, thus double-cropping is more plausible.
- Very sensitive to inputs of fertilizer and water.
- Irrigation expanded and scientifically controlled.

- Fertilizer
  - Can improve yields dramatically: 20-1000%
  - Diminished response if keep adding
  - Reduces growth at high levels
  - Effectiveness depends on
    - Water/Irrigation
    - Timing of application
- Biggest increase could be in Africa
  - Dem. Rep. Congo uses 1% fertilizer used in South Africa

Cassava in Gambia

- Animal Traction
  - 400 million draft animals in world
  - ½ World's ag land farmed with draft animals
  - ¼ farmed with hand tools
  - ¼ mechanized

Vietnam

Draft Animals

- Do the work of 3-4 humans
- Increase land able to be farmed
- Animal plowing breaks soil better than by hand
- Source of fertilizer
- Initial cost high
  - Profitable if can expand land

Zimbabwe

- Poorest farmers will consider moving from hand tools to animals
- Farmers using animals will consider using machinery
- May not be efficient choice:
  - Credit limited
  - Gas expensive
  - Maintenance expensive
  - But labor cheap

Problems with the Green Revolution

- High-yielding, disease-resistant crops are dependent on fertilizer and pesticide application, adequate water, and mechanized farming
- Poor farmers don't have access to the seeds, fertilizers, pesticides, irrigation, and farm equipment necessary to grow these crops

Problems with the Green Revolution

- Green Revolution hasn't alleviated hunger
- Economic power, land controlled by few
- Technology benefits wealthy
- Therefore Green Revolution increases inequity
- More hunger AND more food at same time

Problems with the Green Revolution

- Food Insecurity of poor not addressed
- Cash Crops: food flows from the poor and hungry nations to the rich and well-fed nations
- Green Revolution not sustainable
  - destroys resource base on which agriculture depends

Example: India

India

- Self-sufficient in grain due to Green Revolution
- But 1/3 of people poor
- 5,000 children die each day
- Poor cannot afford to BUY the food

Criticisms of the Green Revolution

- Early, poor had little access to credit
- Could not buy seeds, fertilizer, irrigation to make Green Revolution work
- Wealthy invested, got richer, drove out poor
- Now, more emphasis on loans for poor

There are still problems

- Need good land (wealthy own)
- Agrochemicals bad for health, environment
- Expensive inputs: profits to global chemical companies
- Rural people displaced from land
- Mechanization reduces agricultural jobs
- Not ecologically sustainable: depletes soil, pesticide race

Philippines Example

- Two villages studied:
  - **large and small farmers invested in Green Revolution**
- Village 1 had more equal land holdings, solidarity
  - **All benefited from Green Revolution**
- Village 2 dominated by a few wealthy landowners.
  - **Wealthy increased land by 50% at expense of poor**

Farm Squeeze

- Fertilizer use increases by huge amount
- Yields do not increase proportionally
- India: 6x rise in fertilizer use but 2/3 less production/ton fertilizer
- Need more fertilizer, pesticide each year for same result
- Thus cost go up faster than yields: cost-price squeeze

Farm Squeeze

- U.S. true home of Green Revolution
- Yields up 3x
  - but prices down
- To survive, must expand acreage
  - to make up for lower per acre profit.

Reduced farm income

- In 1900 an American farmer received some 70 percent of every dollar spent on food.
- By 1990 U.S. farmers received an estimated 3 to 4 percent of the money spent on food.

U.S. Farm Squeeze

- Since WWII

  –number of farms decreased 2/3

  –average farm size up ½

  –rural communities gutted

  –production costs up from 50% of gross to 80%

Big Growers More Efficient?

Brazil Farm

- Are big growers more efficient?
  - have the know-how to produce
- Would redistribution of land would lower production?
  - hurt the hungry?

- Big Growers are actually less efficient than small growers in yield/acre

- Often land left idle by large landowners (89% in Brazil)

- Big operations are fossil fuel intensive requiring 10 Calories for every one produced: NeoCaloric Ag

Big Growers

- In North Dakota most “farms” now are greater than 8,000 hectares,
- they are not single properties. Most often consist of many small farms 50 to 100 miles apart.
- such farms are less efficient to operate
- easier to farm single crops

- A 1992 U.S. agricultural census found that smaller farms are two to ten times more productive than larger ones and ten times more productive per acre than farms of 6,000 acres or more.

- The smallest farms (1.6 hectares or less) were 100 times more productive per acre than farms of 2,400 hectares or more.

Tanzania

- Small farmers use labor more intensively
- Small farmers use space more efficiently
- Small landowners more motivated for production and conservation

Big Growers

- Advantages of wealth and size
  - Big farms can more easily survive
- Large operations with absentee owners (investors) tend to:
  - Overuse the soil
  - Over-spray with chemicals
  - Remove wealth generated from the community

Land Reform

- World Bank: productivity would be increased if land distribution more equitable
- Land reform (redistribution) successful after WWII:
  - **South Korea,**
  - **Taiwan**
  - **China**
- Recent success
  - **Japan**
  - **Zimbabwe**
  - **Kerala, India**

Kerala, India

Kerala State: A Social Justice Model

Quality-of-Life Indicators, 1991

Indicator	*Kerala*	*India*	*Low-Income Countries*	*United States*
Per capita GNP ($)	298	330	350	22,240
Adult literacy rate (%)	91	52	55	96
Life expectancy (years)	71	60	55	76
Infant mortality (per 1,000)	17	85	91	9
Birth rate (per 1,000)	20	31	38	16

Source: Kerala, Radical Reform as Development in an Indian State.

Problems with the Green Revolution

- Other problems include:
  - high energy costs
  - environmental damage
  - loss of genetic diversity

Monocultures

- Growing the same crop, year after year, over a large region
- Practice typical of modern agriculture
- Encouraged by increasing mechanization of farming and specialization of farming machines
- Further enabled by chemical fertilizers and pesticides

The rate of genetic erosion has increased since the Green Revolution in the 1960s

- In 1959, Sri Lankan farmers grew more than 2,000 traditional varieties of rice; today they grow 5
- India, is rapidly replacing 30,000 varieties of rice with a single variety.
- By the year 2000, 75 percent of the world's food came from just seven crops—wheat, rice, corn, potatoes, barley, cassava, and sorghum.
- It is estimated that the US has lost 90% of the seed varieties brought here before 1950

Crop Genetic Vulnerability

CANADA

CROP	VARIETIES	%
Bread Wheat	4	75.9
Flax	4	92.3
Rapeseed	4	95.8
Oats	4	65.1
Barley	3	63.7
Rye	4	80.5

USA

CROP	VARIETIES	%
Millet	3	100
Cotton	3	53
Soybeans	6	56
Dry Beans	2	60
Snap Beans	3	76
Peas	2	96
Corn	6	71
Potatoes	4	72
Sweet Potatoes	1	69

Sources *The Prairie Pools: Crop Acreage Report*, 1978
US National Academy of Sciences, 1972

Modern agroecosystems are shockingly dependent on a handful of crop varieties. Homogeneity means vulnerability to pests

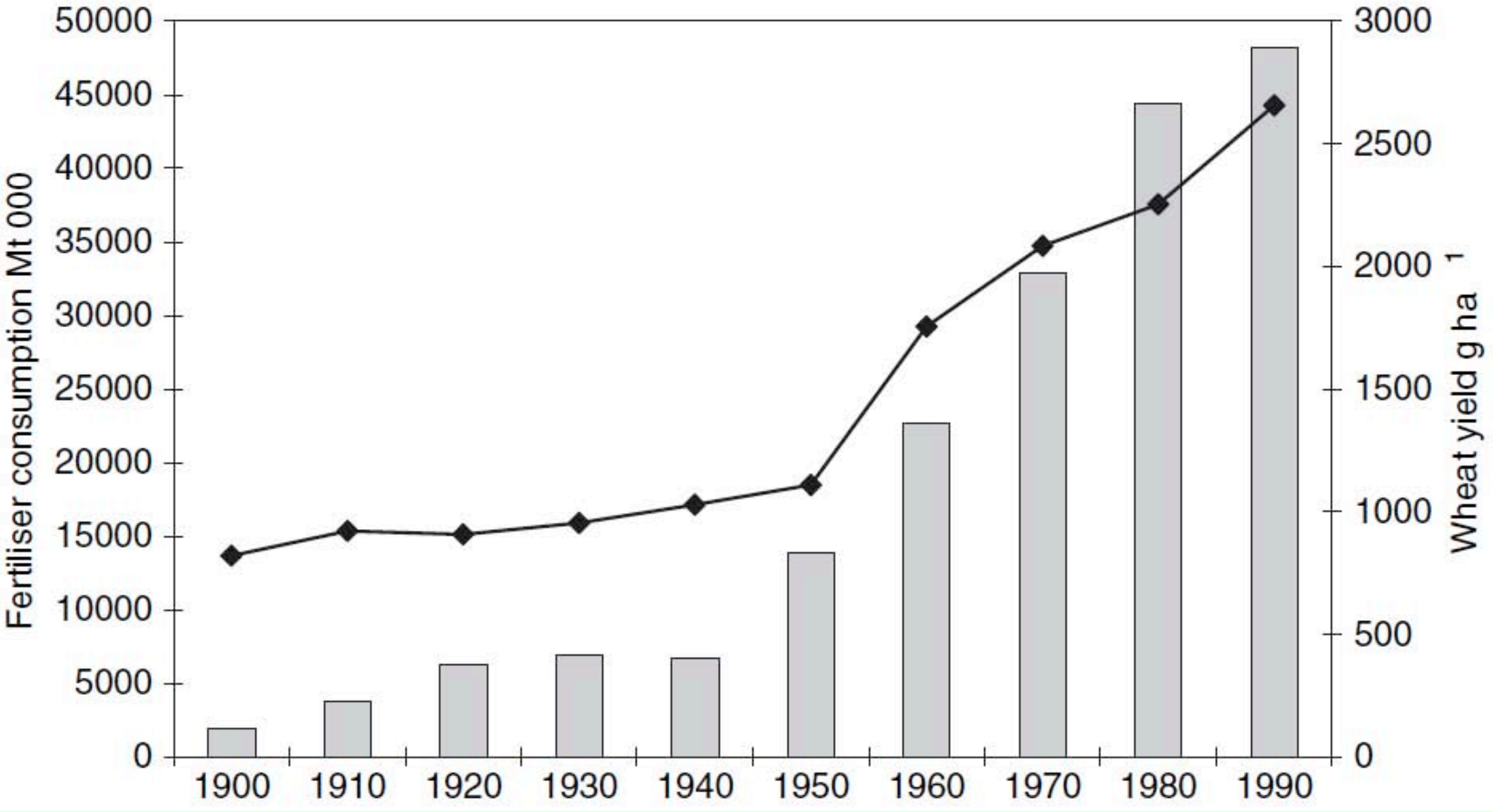
Seed Banks

- To address the threat of genetic erosion, the US and other countries began establishing national repositories for the preservation of seeds of crop plant varieties and their wild relatives
- Non-profit international efforts are also in place to preserve the genetic diversity of the world's crop plants (e.g., Global Crop Diversity Trust)

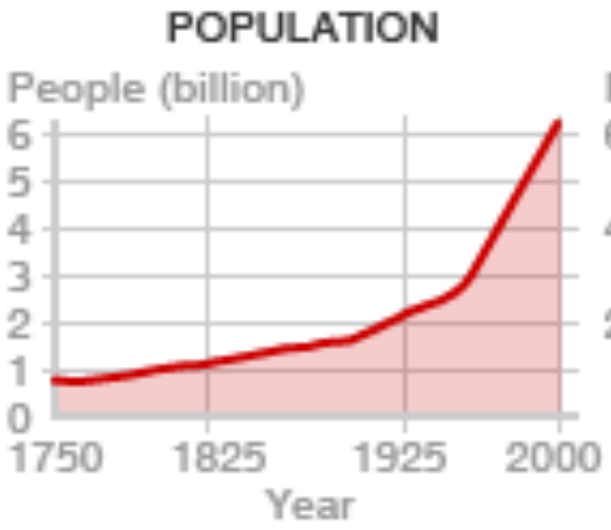
Svarlbard International Seed Vault, Arctic Circle

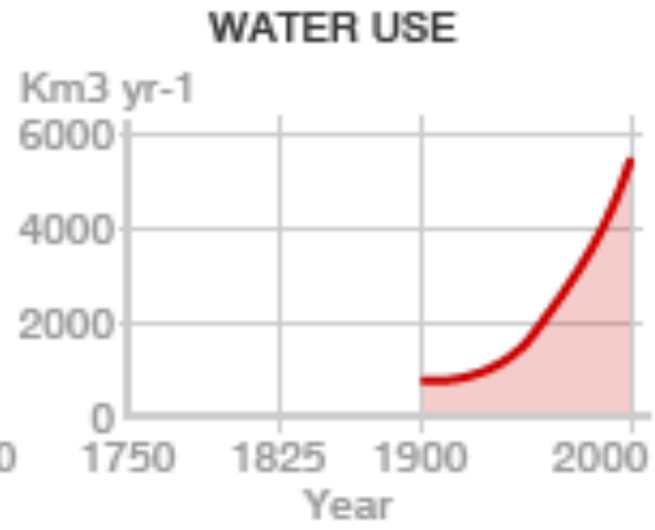
Technical and Resource Limitation Problems

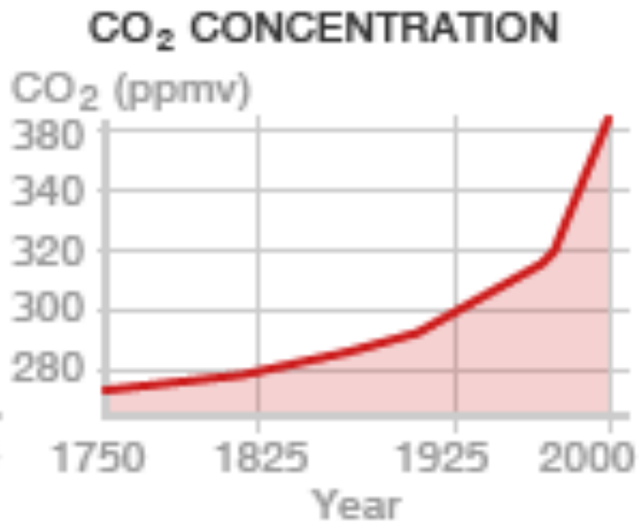
- Heavy Use of Fresh Water
- High Dependence on Technology and Machinery Provided/Sold by Core Countries
- Heavy Use of Pesticides and Fertilizer
- Reduced Genetic Diversity / Increased Blight Vulnerability
- Questionable Overall Sustainability

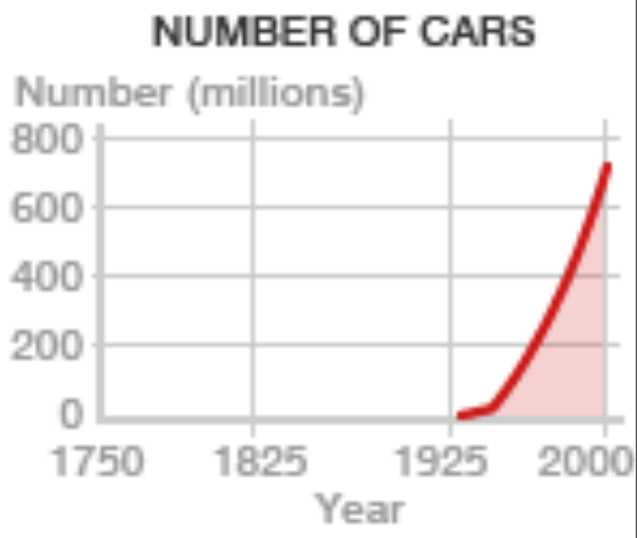


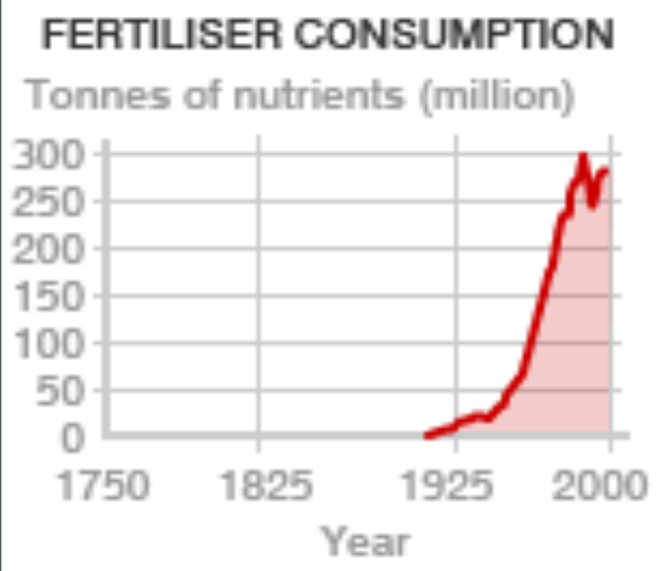
Fertiliser consumption (bars) and yield of wheat (solid line) in the United States 1900–90.
(Source: USDA, www.usda.gov/, last accessed 2006)

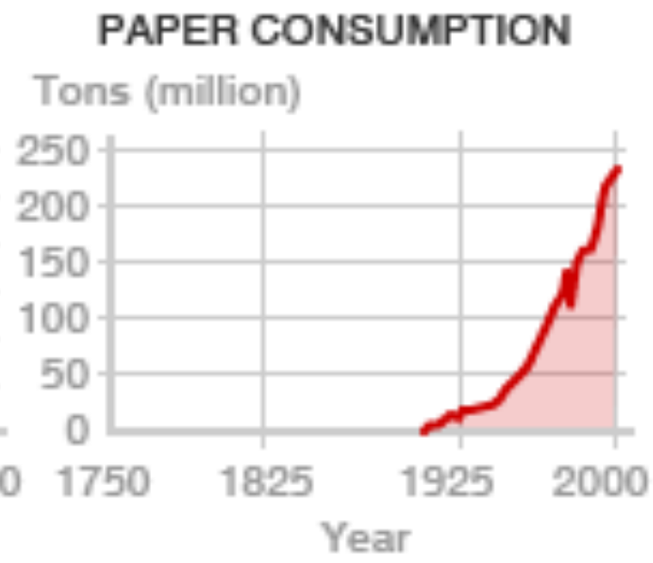


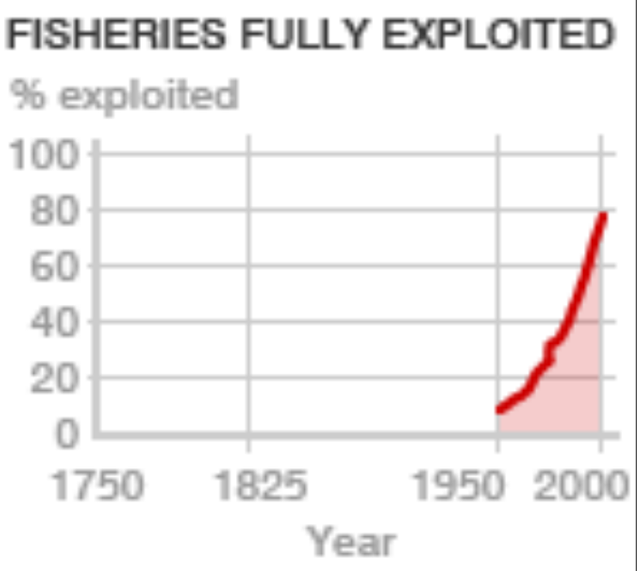












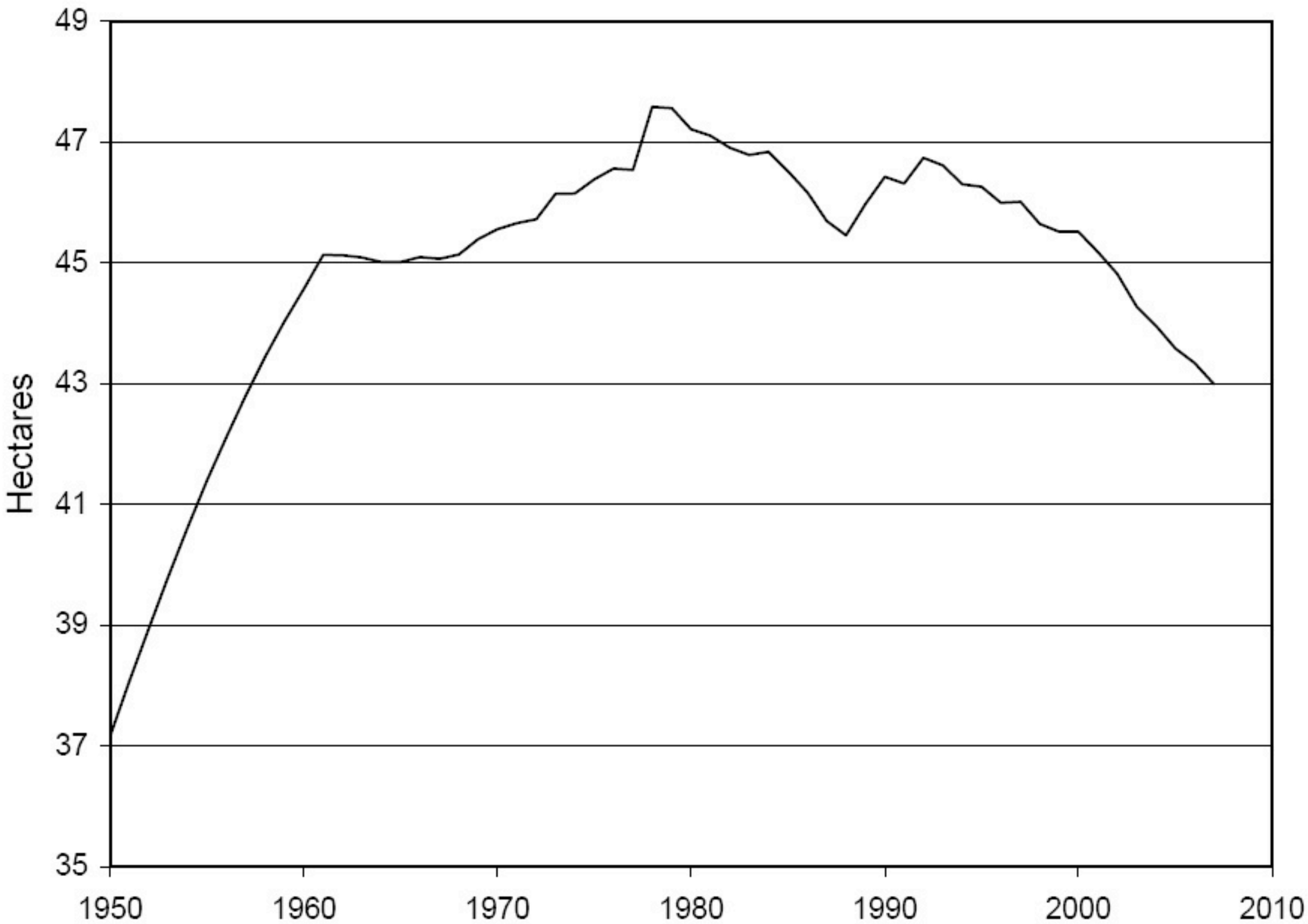
SOURCE: International Geosphere-Biosphere Programme (Steffen et al 2004)

Green Revolution Legacy

Positive results:

- Starvation of many prevented.
- Life expectancy in less developed countries increased by 10 years in less than two decades (43 in 1950's to 53 in 1970's).

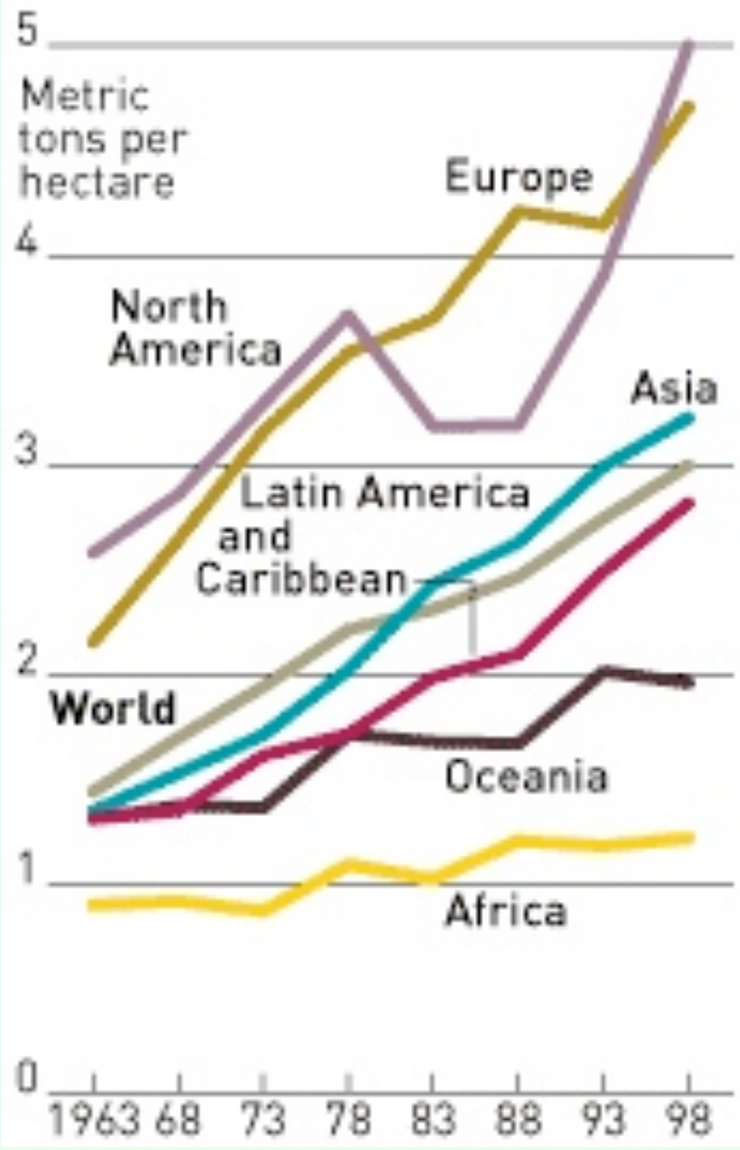
World Irrigated Area Per Thousand People, 1950-2007



Source: Worldwatch, FAO, UNPop

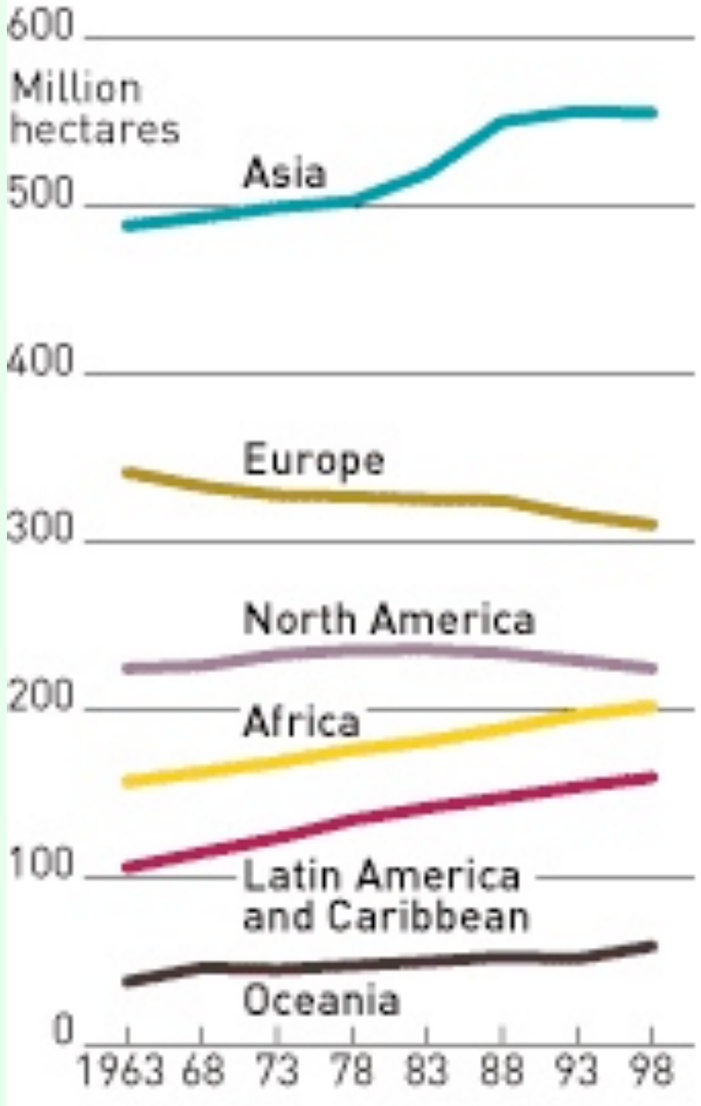
WORLD CROP YIELDS

Cereals, by region



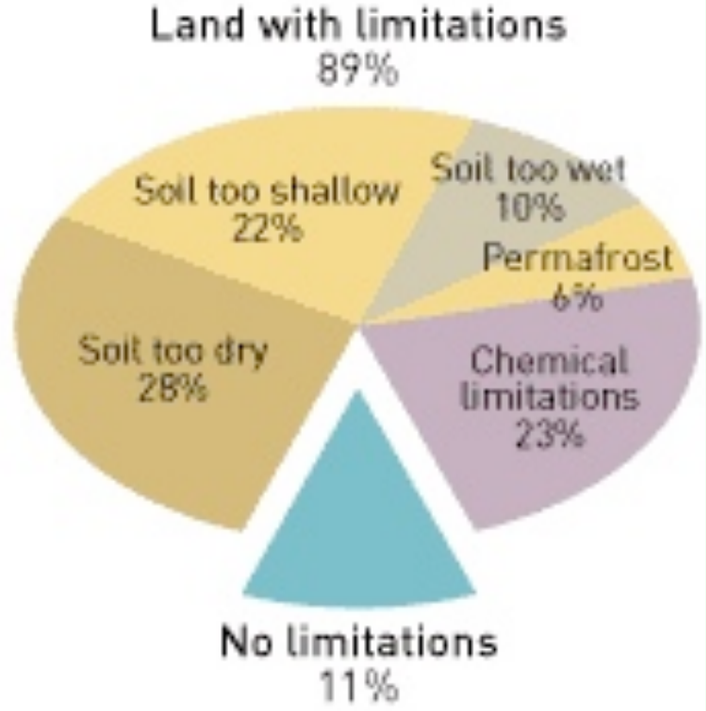
WORLD ARABLE AND CROPLAND

By region



Source: FAO.

GLOBAL SOIL LIMITATIONS TO AGRICULTURE



Source: FAO.

Forest Cover and Loss

- 8000 years ago about 50% of the earth was forest. Today about 30% of the planet is forested (FAO, 2005).
- That's a total loss of about 40%.
- Many of today's forests are modified by humans (second- or third-growth).

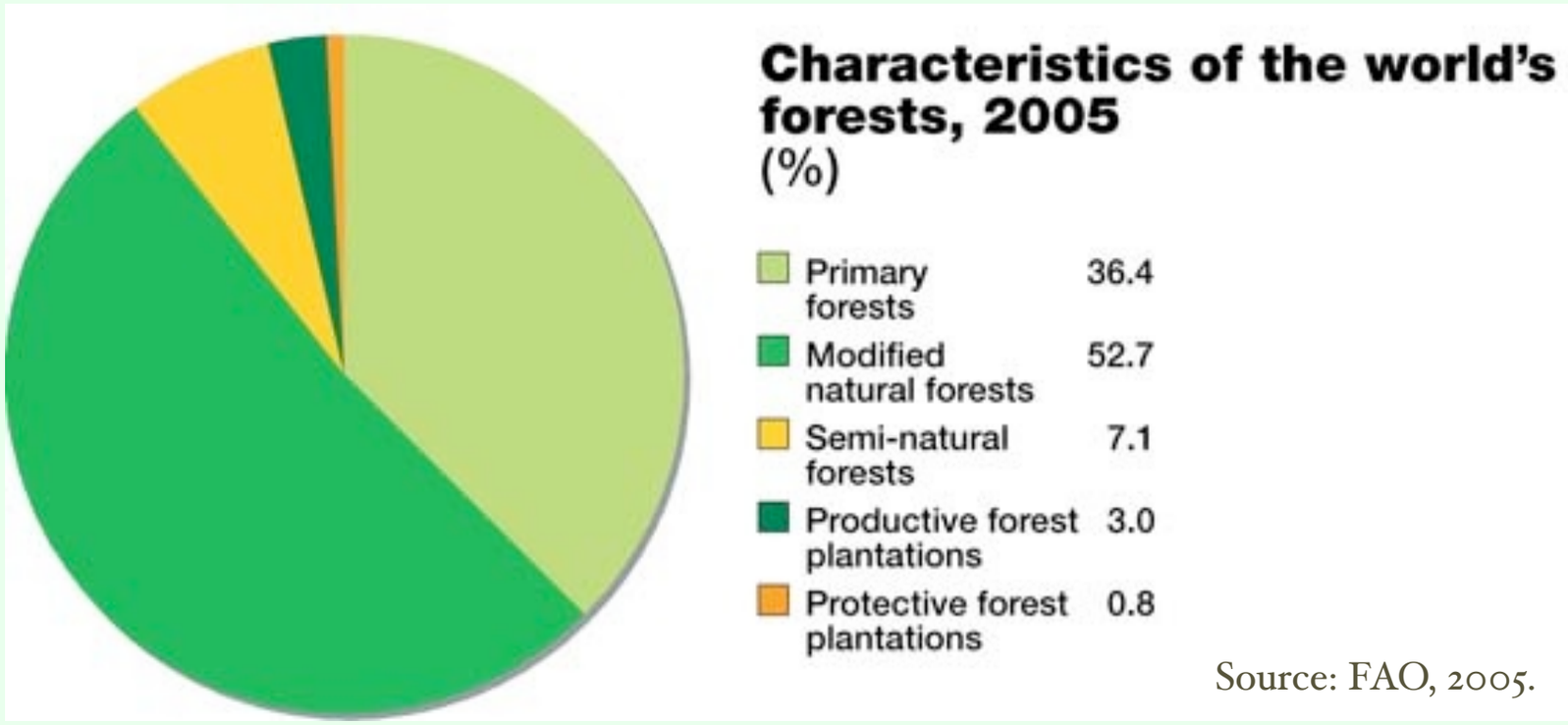


Table 2.3 Agricultural losses to pests in the United States

Year	*Percentage of annual crop lost to*			
	Insects	*Diseases*	*Weeds*	*Total*
1942–1950 (average)	7	11	14	32
1951–1960 (average)	13	12	9	34
1974	13	12	8	33
1984	13	12	12	37

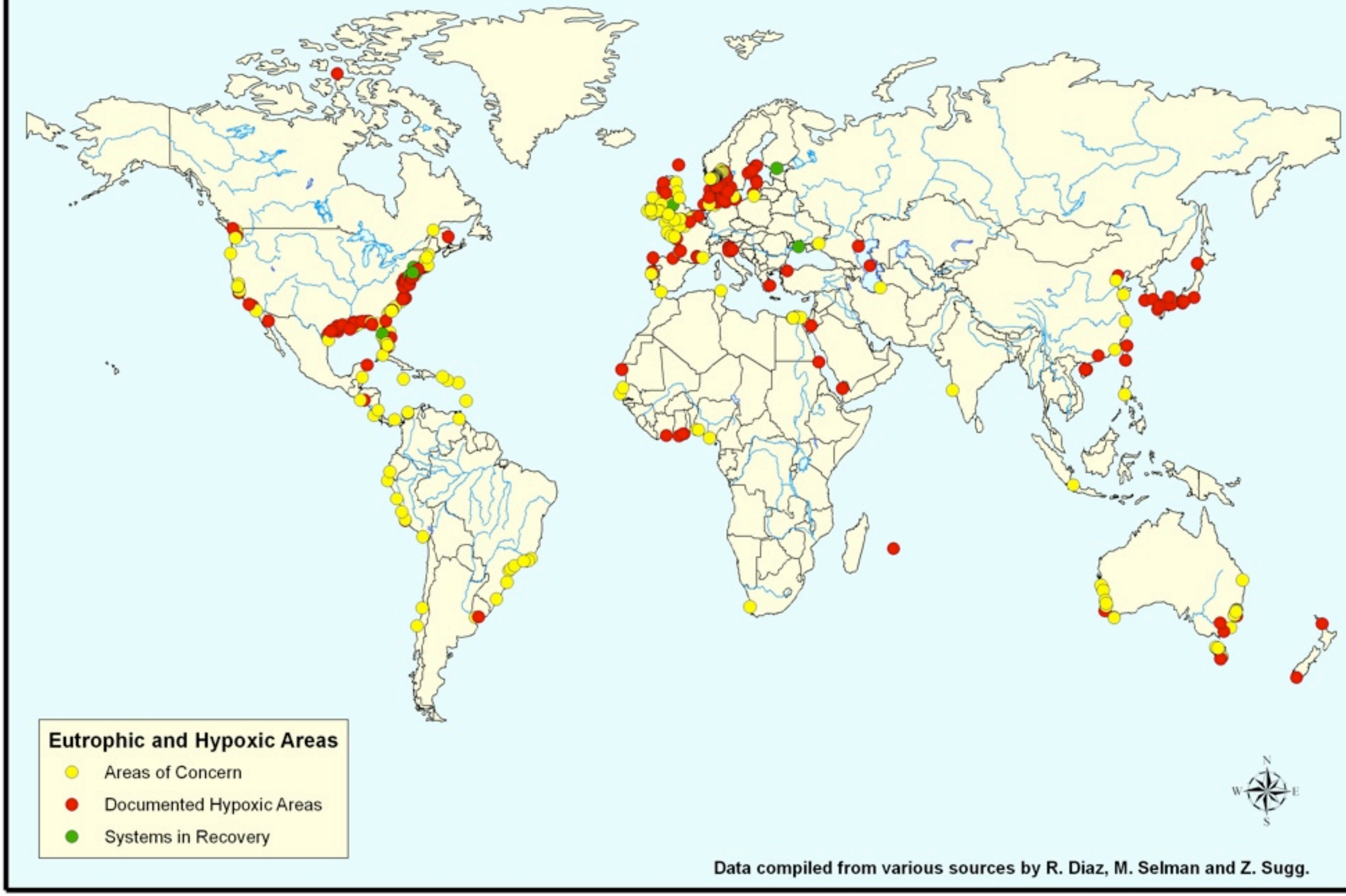
Source: May, R.M., "Food lost to pests", *Nature* 267 (1977) pp. 669–70.

Today yield losses due to pests are the same as 40 years ago despite the fact that more than 4 million pounds of pesticides are yearly injected into the world's environments.

Eytrophication & Hypoxia

- The flux of nitrogen has doubled over natural values while the flux of phosphorus has tripled.
- The effects of nutrient pollution in coastal waters may include:
  - excessive growth of algae, including harmful algae species that can cause fish kills and shellfish poisoning in humans
  - reduced species diversity and dominance of gelatinous organisms such as jellyfish
  - damage to coral reefs
  - and formation of oxygen-depleted “dead zones.”

World Hypoxic and Eutrophic Coastal Areas



Data compiled from various sources by R. Diaz, M. Selman and Z. Sugg.

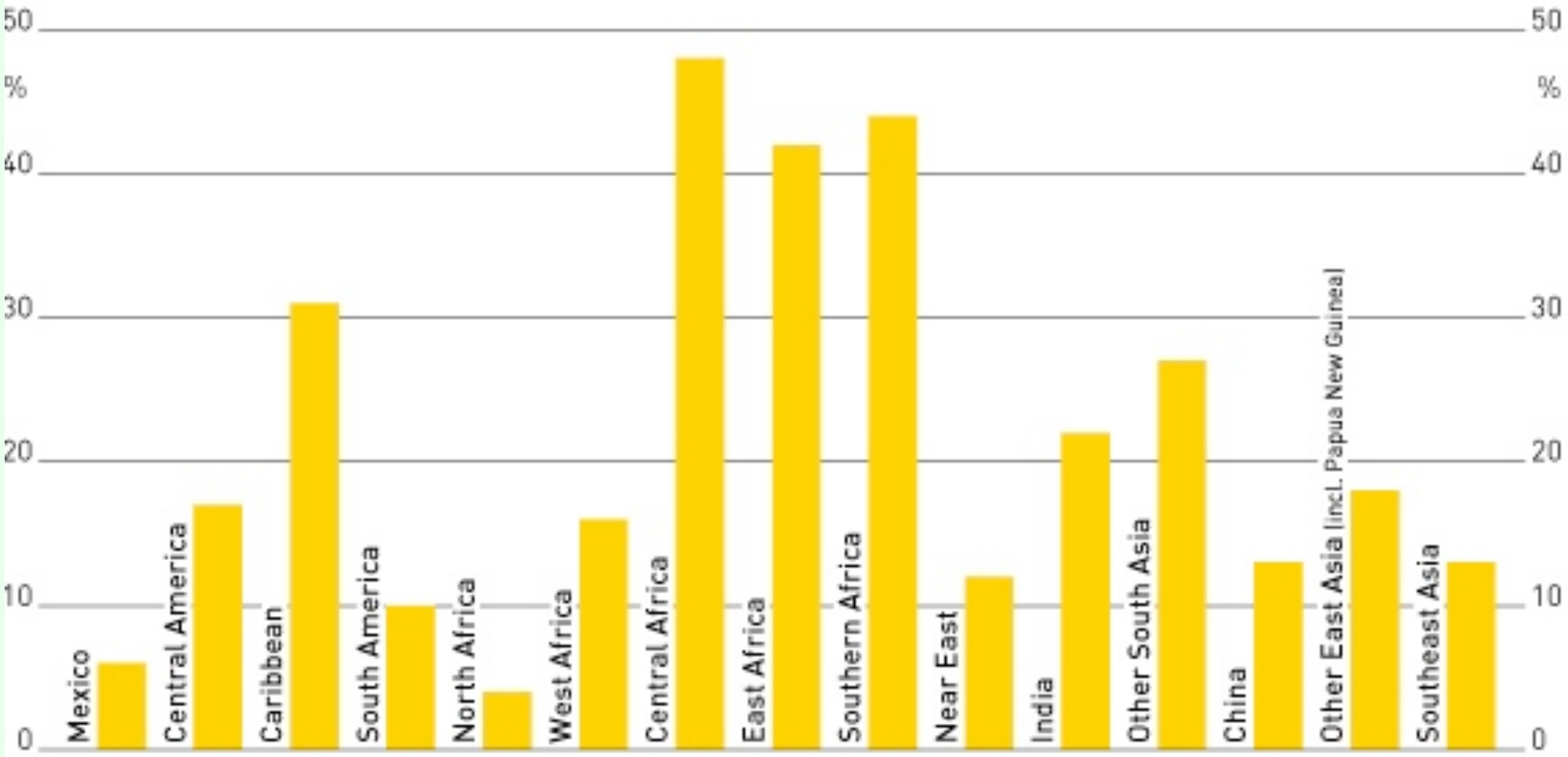
Green Revolution Legacy

Negative results:

- Dependency on core countries increased.
- Wealthy farmers and multinational companies do well.
- Small farmers become wage laborers or unemployed.
- More at risk? More people malnourished/ starving today than in 1950.

UNDERNOURISHMENT IN THE DEVELOPING WORLD, LATE 1990s

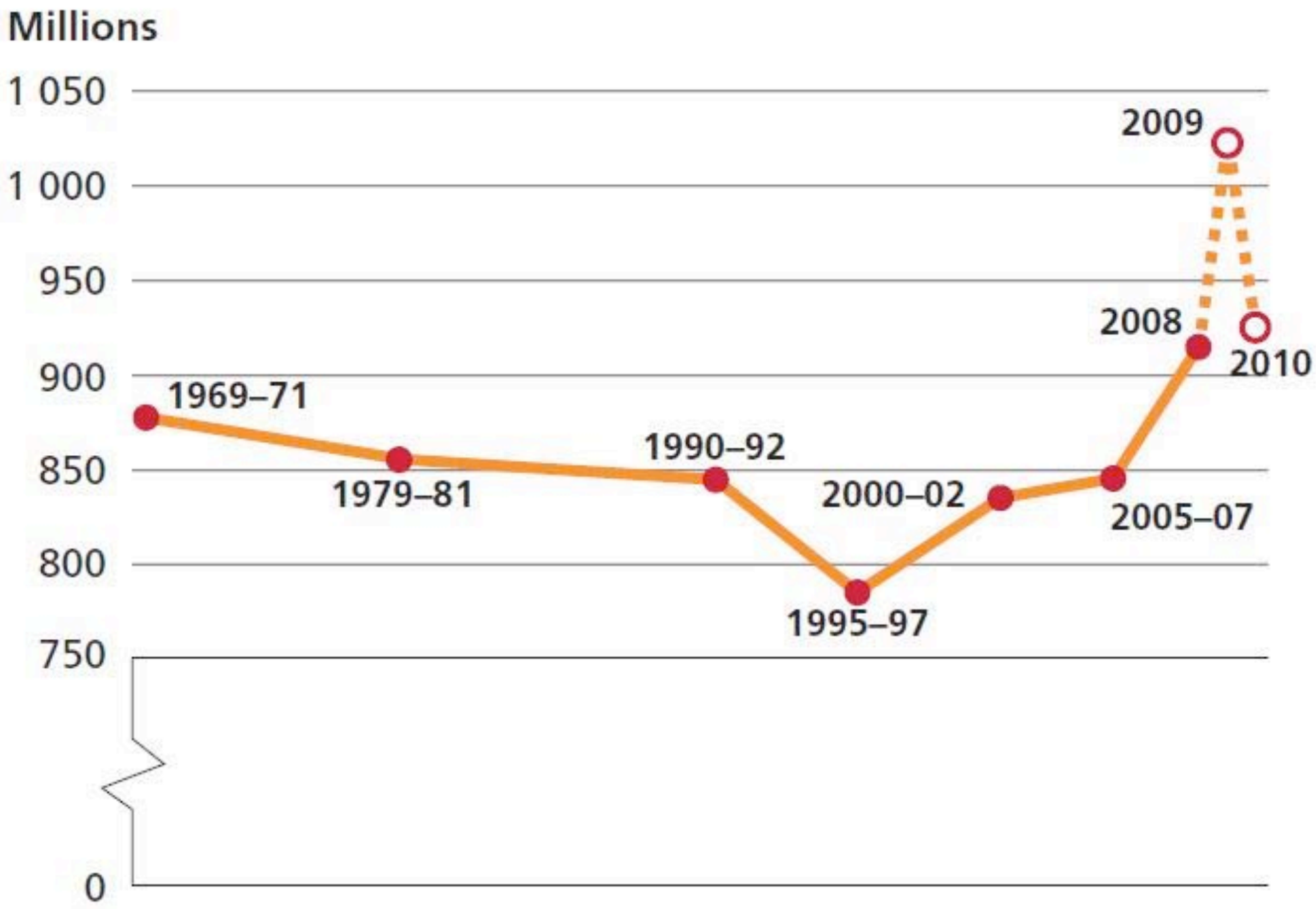
As a proportion of the total population



Note: Undernourishment in the industrialized world averages less than 2.5%, with most of this in the countries in transition of Eastern Europe and the former USSR.

Source: FAO.

Number of undernourished people in the world, 1969–71 to 2010



Note: Figures for 2009 and 2010 are estimated by FAO with input from the United States Department of Agriculture, Economic Research Service.

Source: FAO.

Social Issues - Farm labor

- When designing a sustainable system, what role does farm labor play?
- Do we want to reduce labor needs with increase mechanization & use of technology?
- Or, do we want to increase labor demands to meet employment needs of local population?
- Can you think of situations when either of the above would be appropriate?

Challenges facing modern agriculture

- Agronomic: increased population; food production; nutrition; food security
- Environmental: Soil, Water, Air, Biodiversity; the footprint of agriculture
    - Economic: Farmers and Rural Communities
- Developed and Developing Countries
    - Demands differ somewhat but all three challenges apply
- Biofuels: impact on food security and food cost